INVESTIGATION OF GENERATION MECHANISMS OF THE POST-MIDNIGHT F-REGION IRREGULARITIES

A synopsis submitted

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by

Meenakshi S

SC19D022

Department of Physics
Indian Institute of Space Science and Technology
Thiruvananthapuram, India

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Abstract

F-region irregularities develop under unique conditions of low magnetic inclination, eastward zonal electric field and vertical transport of plasma. These ionospheric irregularities are vastly studied for better prediction of the ionosphere. The F-region irregularities are usually observed during post-sunset hours. However, in solar minimum years, these irregularities are observed during delayed hours or around midnight hours and they are traditionally called the post-midnight F-region irregularities (PMF). The Rayleigh Taylor Instability (RTI) is considered to be the mechanism behind these irregularities. Studies have been conducted in this dissertation to determine the lower atmospheric forcing as well as the impact of the thermospheric winds on the post-midnight F-region irregularities.

The Equatorial Atmosphere Radar (EAR) observations at Kototabang (0.2°S, 100.3°E) are used to study the possible semidiurnal tidal influence on the occurrence of post-midnight F-region Field-Aligned Irregularities (FAI) echoes. It is found that the post-midnight FAI echoes show high percentage of occurrence (PO) during June–July and low PO in December–January of low solar activity years. As solar activity approaches minimum, the PO increase is extended to May, August, and September. The space-time Fourier analysis on the temperature information obtained from the Sounding of Atmosphere by Broadband Emission Radiometry (SABER) instrument onboard Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) satellite reveals that at the low-latitude upper mesospheric heights, though the migrating diurnal tide propagating westward with zonal wavenumber (k) 1 (DW1) dominates the migrating semidiurnal tide propagating westward with k = 2 (SW2) during the equinox months, the SW2 tidal amplitudes are larger than DW1 during June–July. This indicates that the SW2 have a major role to play in the generation of the PMF.

The post-midnight F-region irregularities have low PO during boreal winter months. The ionosonde observations from Gadanki (13.4593° N, 79.1684° E) have shown that there is an increase in the PO of post-midnight spread-F (PMSF) during boreal sudden stratospheric warming (SSW) which occurred in December 2018- January 2019. The EAR observations also showed high PO of the post-midnight F-region FAI echoes during December 2018-January 2019. From the analysis of the tidal amplitudes from SABER temperature, the SW2 amplitude is found to be enhanced compared to the DW1 during boreal SSW of 2018-19. The hmF_2 (peak electron density height of F-region) and hpF (virtual height of the bottomside F-

region) is also found to have increased around midnight hours. The SW2 enhancement and the F layer uplift around midnight hours could have created conditions favouring the growth of the PMF.

From 2011-2019 EAR observations, an anomalous increase in the PO of post-midnight F-region FAI echoes is found in the equinox month of September 2019 which is investigated further. Inter-annual variability in PO for September also shows maximum PO in 2019 compared to other years even after removing geomagnetically disturbed days indicating the lower atmospheric dynamical forcing. Coincidently, an austral polar sudden stratospheric warming (SSW) event has occurred during September 2019, which precedes large planetary wave activity. Due to the circulation changes associated with the SSW, though the enhancement of ozone over the equatorial stratosphere is inferred from the space-borne SABER measurements, the expected increase in the amplitude of the upper mesospheric migrating semi-diurnal tide (SW2) is not observed in SABER temperature. But there is a drastic decrease in the amplitude of the DW1. The enhancement of stationary diurnal tide (DS0) suggests that the DW1 may have interacted with the planetary wave of zonal wavenumber 1 to generate DS0 at the expense of the DW1 tide.

Longitudinal variability in the PO of post-midnight F-region irregularities during Austral SSW of 2019 is determined using ionosonde measurements. The analysis of digisonde ionograms of Ascension Island (7.9°S, 14.4°W geographic; dip latitude: 16°S) for the geomagnetically quiet days shows a high percentage of occurrence (PO) of post-midnight spread F (PMSF) in September 2019. However, Jicamarca (11.95°S, 76.87°W, dip latitude: 1.10°N) digisonde observations do not show any significant increase in the PO. Besides, the wavelet spectrum of the hmF_2 shows a strong semi-diurnal (12 h) variation over Ascension Island, whereas diurnal (24 h) variation is dominant in Jicamarca. The high PO of PMSF and the semi-diurnal variation indicates the lower atmospheric tidal forcing. The two-dimensional spectral analysis of the space-borne SABER temperature measurements shows that the SW2 tidal amplitude exceeds the DW1 tidal amplitude at 10°N, which is close to the dip equator in the Ascension Island longitude, whereas the DW1 dominates at 10°S over the dip equatorial station, Jicamarca. The SW2 dominated tidal spectrum can drive semi-diurnal variation in the zonal electric field. The dominant semi-diurnal variation of the zonal electric field can become eastward at midnight hours and lift the F-layer to higher heights creating favourable conditions for the growth of the RTI to generate the F-region irregularities around midnight.

The winds and plasma drifts measured by the Michelson Interferometer Global High-resolution Imaging (MIGHTI) and Ion Velocity Meter (IVM) respectively onboard the Ionosphere Connection Explorer (ICON) satellite are used to investigate the seasonal and inter-annual variations of the thermospheric winds and F-region plasma drifts in the solar minimum years 2020-21. It is observed that the daytime vertical plasma drifts are upward, irrespective of season and longitude. Except in the fall equinox of 2020, the nighttime vertical plasma drifts are downward during winter and equinox. Over northern geomagnetic low latitudes, the meridional winds are equatorward during summer and poleward in winter. The meridional winds during nighttime (after 21:00 LST) are weakly poleward or equatorward in the equinox months of 2020, while they are poleward in 2021. Zonal drifts are similar to zonal wind variations with daytime westward and nighttime eastward drifts. While semi-diurnal variation is present in the vertical plasma drifts in summer, diurnal variation predominates in winter. Regardless of the season, diurnal variation is dominant in zonal winds and zonal plasma drifts. From these results, we can infer that the nighttime plasma drifts are upward when equatorward winds are present and downward when strong poleward winds are present. We can deduce that meridional winds may play a role in inducing upward plasma drifts, which may in turn create favourable conditions for the RTI and result in the occurrence of F-region irregularities, given that post-midnight F-region irregularities tend to occur in summer when equatorward winds and upward drifts are present.